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LOCAL ROAD UNIT COSTS In Illinois

By N. G. P. Krausz
and
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CONTENTS

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AN ANALYSIS OF LOCAL ROAD UNIT COSTS IN ILLINOIS

By N. G. P. KRAUSZ and EARL R. SWANSON[1]

Nearly 71 percent of all roads in Illinois, or 73,400 miles, are local rural roads. In 1953 these roads were administered by 1,408 townships in 85 counties with township form of government and by 107 road districts in counties with commission form of government. As of December 31, 1953, the average local road unit[2] in Illinois contained about 48 miles of road. In five commission-governed counties (Alexander, Hardin, Massac, Pulaski, and Williamson) road districts comprise all or nearly all of the county.

Local roads account for a large share of the expenditures by local governments in Illinois. Not only have the number and weight of vehicles increased, but motorists are demanding improved facilities. Construction and maintenance of all-weather surfaces require planning and supervision by trained men, adequate machinery, and large quantities of material. These facts, together with increasing costs, have focused attention on the expenditures and services of local road units.

Purpose of Study

The purpose of this study is to determine the effect of size of road unit on cost per mile of road. Recommendations regarding the optimum size of a road unit would, of course, need to be analyzed in a broader context. In a complete study the total costs of township government would need to be considered. It is hoped, however, that this study will provide a more adequate basis than now exists for economic evaluation of alternative proposals regarding organization of road units.

Approach to the Problem

Among the factors causing variations in road costs are differences in mileage of road maintained, intensity and weight of traffic, number of people served, and quality of road surface maintained. These can all be measured or evaluated more or less directly.

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[2] "Local road unit" or "road unit" is used in this report to refer to any governmental unit responsible for constructing and maintaining local roads. "Local road units" include (1) township highway districts, (2) township districts, (3) road districts, and (4) county unit road districts.

Also of importance are the internal organization and operation of the unit. The amount and adequacy of road equipment, available funds, experience of the road commissioner, and skill of equipment operators affect costs and road quality. Most of these factors are difficult to evaluate directly, but they are reflected in measurable factors. The skill of the road commissioner and equipment operators is reflected in the condition of the road surface. Adequacy of equipment is at least partly reflected in equipment investment. The availability of housing for equipment should be reflected in lower maintenance and replacement costs.

Other factors affecting road costs are even more difficult to evaluate. These arise mostly from differences in soil, climate, and topography. Physical features such as hills and streams affect the location of roads and the number of bridges and culverts maintained. Drainage and erosion problems, frost damage, snow and rainfall, as well as availability of materials, also affect road costs. The study was conducted in such a way as to minimize the effect of conditions that cannot be measured.

Methodology

Part I of the study utilized local road data for one year — 1953 — which were made available by the Division of Highways. Statistical analyses were made of maintenance and administrative costs as related to total mileage of the units within each state highway district (Fig. 1), and construction costs as related to number of miles built. Using cost and mileage data from 1,491 road units provided statistical accuracy even though there may be considerable variation in any one district from year to year.

In Part II an intensive first-hand study was made of eleven road units: four in northern, three in central, and four in southern Illinois. The purpose was to obtain a subjective evaluation of road conditions, equipment, and buildings, as well as other first-hand information. It was hoped that this information would provide guidance in the use and interpretation of secondary data obtained from the Division of Highways.

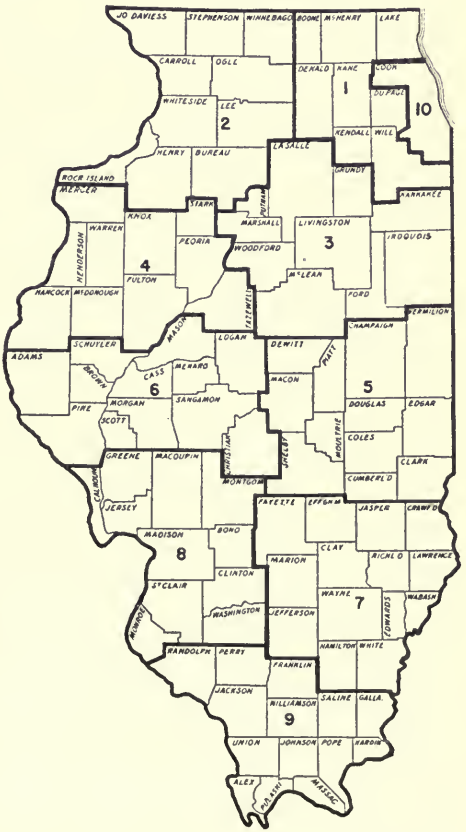
The eleven road units were carefully selected, so that they would be similar in topography but have a wide range in mileage. Financial reports of these units were compared, and township equipment and roads were examined and evaluated. In addition, personal interviews were held with township road commissioners and other local officials.

Part I — A Statistical Study of the Costs of 1,491 Road Units and 1,006 Construction Projects

Sources of data

Local road units submit cost data for construction, as well as descriptions of construction projects, to the Division of Highways in connection with the administration of the Motor Fuel Tax funds. In addition, the Division of Highways collects data on other receipts and expenditures by the road units.

Reports for the fiscal year 1953-54 were used for this study. All costs reported from each of the road units were divided into three categories: maintenance, administration, and construction. Maintenance costs include all direct labor involved in maintenance operations, operating expenses, and the share of machinery and equipment overhead costs not charged to construction. Administration costs are composed chiefly of the commissioner's salary.



The Division of Highways has established ten state highway districts in Illinois for administrative purposes. In this study local road units were grouped into highway districts before analyses were made. Since the study is concerned only with rural roads, District 10 (Cook county) is omitted from the analyses. (Fig. 1)

The miles of each type of road surface in each local road unit were also obtained (Table 1). These data were made available by the Division of Highways, which had collected the data in cooperation with the Bureau of Public Roads of the Department of Commerce.

Analysis

The central problem in the analysis was that of isolating, insofar as possible, the relationship between per-mile costs and the mileage administered by the unit. To help minimize the effects of such factors as physical characteristics of the soil, topography, and snowfall on costs, the units were grouped into highway districts (Fig. 1). This grouping also reduced the effect of differences among units with respect to wage rates and costs of construction and maintenance materials. Another help in isolating the relationship between per-mile costs and mileage administered by the unit was the division of costs into maintenance, administration, and construction. The separate analysis on construction costs made it possible to take into account the cost differences among units that were due to different mileages of construction in 1953.

After the units were grouped into districts and costs classified, the average relationship between per-mile costs and mileage was computed for every size of unit that existed in the district. The multiple regression technic, briefly described in the Appendix (page 21) was used. In essence, the technic is an averaging process which in this instance was used to summarize the effects of mileage on road costs after taking into account other variables.

In the analyses of maintenance and administrative costs, the causative variables included the mileages of each of the eight different types of road surface (Table 1). Since administrative units have the eight types of roads in varying proportions, and costs vary with type of surface, consideration of the mileage of each type of road permitted a more accurate evaluation of the cost relationship than if an aggregate of simply "miles" had been employed. Further, since a preliminary analysis indicated that taxable resources were related to per-mile costs, assessed valuation was included as a variable. This was done to help insure that the effect of mileage on costs was a net effect; that is, it would minimize any distortion of the estimated per-mile cost relationships if the wealthier administrative units, which typically spent more on their roads, also consistently had either low or high mileages to administer.

Table 1. — Average Mileages of Rural Roads Administered by Local Road Units in Illinois, 1953

Type of surface	State highway district[a]									State
	1	2	3	4	5	6	7	8	9[b]	
	Miles									
Unimproved	0.41	0.53	0.44	0.36	0.39	1.28	2.79	0.73	4.75	1.12
Graded and drained earth	2.69	3.03	6.21	6.11	6.11	6.61	14.29	7.05	10.40	6.84
Soil surfaced, primarily oil	0.01	2.40	0.31	0.01	16.29	11.72	5.02	12.04	0.47	5.69
Gravel or stone	36.74	30.44	40.61	36.45	34.30	26.73	34.89	22.89	47.15	33.76
Low-type bituminous (flex base)	5.60	1.20	0.59	0.19	0.89	0.40	0.09	0.03	0.05	0.88
High-type bituminous (solid base)	0.01	0.01	(c)	0.03	0.03	(c)	(c)	(c)	(c)	0.01
Concrete	0.06	0.04	0.01	0.05	0.12	0.03	0.02	0.14	0.15	0.06
Brick	(c)	0.01	0.01	0.02	0.14	0.01	(c)	0.01	0.02	0.02
Total	**45.52**	**37.66**	**48.18**	**43.22**	**58.27**	**46.78**	**57.10**	**42.89**	**62.99**	**48.38**
Number of local road units	**119**	**202**	**202**	**173**	**176**	**182**	**179**	**166**	**94**	**1,493**

[a] See Fig. 1. Highway District 10 (Cook county) is omitted since interest is in rural roads. In the other highway districts, units which are coterminous with municipalities have also been omitted.

[b] Five local road units in District 9 comprise an entire county each.

[c] Less than 0.005 mile.

Table 2. — Maintenance and Administration Costs per Mile[a] of Local Rural Road in Illinois, 1953

Size of local road unit (miles)	State highway district									State[b]
	1	2	3	4	5	6	7	8	9	
	Cost per mile, dollars									
10	722	341	375	383	(c)	547	(c)	300	(c)	...
20	540	295	353	287	325	351	191	236	199	303
30	480	280	346	254	296	285	157	215	147	269
40	450	272	342	238	282	252	140	205	120	253
50	431	267	340	228	273	233	129	198	105	243
60	419	264	338	222	268	220	122	194	96	236
70	410	263	337	217	264	210	117	191	88	231
80	404	(c)	337	214	261	203	113	188	82	...
90	399	...	336	212	259	198	111	187	79	...
100	395	...	335	(c)	256	194	108	(c)	74	...
110	391	...	(c)	...	255	190	107	...	72	...
120	389	...	...	...	253	(c)	105	...	69	...
130	(c)	...	...	...	253	...	(c)	...	68	...
150	...	...	...	...	(c)	...	...	...	65	...
200	...	...	...	...	...	...	...	...	59	...
300	...	...	...	...	...	...	...	...	54	...
400	...	...	...	...	...	...	...	...	51	...
500	...	...	...	...	...	...	...	...	49	...
600	...	...	...	...	...	...	...	...	49	...
Number of road units used to estimate costs	119	202	202	173	176	182	177[d]	166	94	1,491

[a] A mile in each district is a composite of the eight types of road surfaces in the same average proportion as reported in that highway district (Table 1).
[b] Costs for each highway district weighted by the total number of miles in that district. State average costs computed only for mileages within the range of mileages of all districts.
[c] Average costs were not computed for local road units either larger or smaller than any unit in a particular highway district.
[d] Two local road units had incomplete reports; total number of local road units in highway district 7 is 179.

Table 3. — Construction Costs per Mile of Gravel Applied to Graded and Shaped Gravel or Crushed Stone Using Day Labor in Illinois, 1953[a]

	State highway district									
	1	2	3	4	5	6	7	8	9	State[b]
Number of projects	71	48	117	98	32	40	106	48	21	581
Average width, feet	17.48	15.27	15.01	13.41	14.72	14.10	13.17	13.12	12.95	14.42
Average depth, inches	5.68	5.23	4.67	4.19	4.06	3.95	3.10	3.77	3.95	4.29
Average length, miles	1.38	1.73	2.54	1.51	1.75	1.37	1.73	1.65	1.40	1.77
Length of project, miles	*Cost per mile, dollars*									
0.5	4,356	4,280	5,044	4,780	6,010	5,098	4,490	3,714	6,760	4,759
1.0	3,700	3,643	3,349	3,486	4,033	3,831	3,452	3,198	5,834	3,606
1.5	3,481	3,431	2,784	3,054	3,374	3,409	3,105	3,025	5,525	3,221
2.0	3,372	3,325	2,502	2,839	3,045	3,198	2,933	2,939	5,370	3,029
2.5	3,306	3,261	2,332	2,709	2,847	3,072	2,828	2,888	5,278	2,914
3.0	3,262	3,219	2,219	2,623	2,715	2,987	2,759	2,853	5,216	2,837
3.5	3,231	3,189	2,139	2,561	2,621	(c)	2,710	2,828	(c)	.....
4.0	(c)	3,166	2,078	2,515	2,551	.....	2,673	2,810	.....	.....
4.5	.....	3,148	2,031	(c)	2,496	.....	2,644	2,796	.....	.....
5.0	.....	3,134	1,993	.....	2,452	.....	(c)	(c)	.....	.....
5.5	.....	3,122	1,962	.....	2,416	.....	.....	.....	.....	.....
6.0	.....	(c)	1,937	.....	2,386	.....	.....	.....	.....	.....
6.5	.....	.....	1,915	.....	2,360	.....	.....	.....	.....	.....
7.0	.....	.....	1,896	.....	2,339	.....	.....	.....	.....	.....
7.5	.....	.....	1,880	.....	2,320	.....	.....	.....	.....	.....
8.0	.....	.....	1,866	.....	2,303	.....	.....	.....	.....	.....
8.5	.....	.....	1,854	.....	2,289	.....	.....	.....	.....	.....
9.0	.....	.....	1,843	.....	(c)	.....	.....	.....	.....	.....
9.5	.....	.....	1,833	.....	.....	.....	.....	.....	.....	.....
10.0	.....	.....	1,824	.....	.....	.....	.....	.....	.....	.....

[a] Construction performed with equipment and personnel of local road administrative unit with necessary additional labor hired by the day.
[b] Costs for each highway district weighted by the number of projects in that district. State average costs computed only for mileages within the range of all highway districts.
[c] Average costs were not computed for projects smaller or larger than any project in that particular highway district.

Table 4. — Costs per Mile of Different Kinds of Road Construction in Illinois, 1953

Type of construction....	Gravel applied on ungraded gravel or earth (day labor)[a]	Gravel applied on gravel or stone (contract)[b]		Low-type bituminous applied on gravel or stone (contract)[b]	Oil applied on graded earth or oil (day labor)[a]					Oil applied on gravel or stone (day labor)[a]	
Highway district[c].....	7	5	7	1	5	6	7	8	9	7	8
Number of projects.....	17	21	22	39	66	37	67	108	19	15	14
Average width, feet.....	12.71	13.62	12.64	18.08	13.91	14.49	13.58	13.91	14.53	13.87	15.29
Average depth, inches...	3.59	3.24	3.82	[d]	.....	.....	.....	.....	.....	.....	.....
Average length, miles...	1.65	1.65	1.76	1.69	3.07	3.94	2.59	2.61	2.55	2.18	2.08
Length of project, miles	*Cost per mile, dollars*										
0.5.....	4,162	4,648	4,638	8,326	2,493	3,277	2,717	1,465	2,202	1,553	1,747
1.0.....	3,791	3,925	3,617	5,761	1,519	1,913	1,757	1,248	1,708	1,385	1,392
1.5.....	3,668	3,685	3,277	5,025	1,194	1,458	1,437	1,176	1,543	1,329	1,274
2.0.....	3,606	3,564	3,106	4,478	1,032	1,231	1,277	1,139	1,461	1,301	1,215
2.5.....	3,569	3,492	3,004	4,221	935	1,095	1,181	1,118	1,411	1,284	1,180
3.0.....	3,544	3,444	2,936	4,051	870	1,004	1,118	1,103	1,378	1,273	1,156
3.5.....	3,526	3,409	2,888	3,928	823	939	1,072	1,093	1,355	1,265	1,139
4.0.....	[e]	[e]	2,851	3,836	789	890	1,038	1,085	1,337	1,259	1,126
4.5.....	.....	.....	[e]	3,765	762	852	1,011	1,079	1,323	1,254	1,116
5.0.....	.....	.....	.....	3,708	740	822	990	1,074	1,312	1,250	1,109
5.5.....	.....	.....	.....	3,661	722	797	972	1,070	1,303	[e]	1,102
6.0.....	.....	.....	.....	3,622	707	776	958	1,067	1,296	.....	[e]
6.5.....	.....	.....	.....	3,590	695	759	945	1,064	1,289	.....	.....
7.0.....	.....	.....	.....	3,561	684	744	935	[e]	1,284	.....	.....
7.5.....	.....	.....	.....	3,537	675	731	926	.....	1,279	.....	.....
8.0.....	.....	.....	.....	3,516	667	720	[e]	.....	[e]	.....	.....
8.5.....	.....	.....	.....	3,497	660	710	.....	.....	.....	.....	.....
9.0.....	.....	.....	.....	3,480	653	701	.....	.....	.....	.....	.....
9.5.....	.....	.....	.....	3,465	[e]	693	.....	.....	.....	.....	.....
10.0.....	.....	.....	.....	3,451	.....	686	.....	.....	.....	.....	.....

[a] Construction performed with equipment and personnel of road administrative unit with necessary additional labor hired by the day. Costs include a charge for owned equipment.

[b] Construction project contracted out.

[c] Not all districts had enough construction projects to warrant analysis.

[d] Not reported.

[e] Average costs were not computed for projects larger than the largest projects actually underway in a particular highway district.

The multiple regression technic was also used to estimate costs per mile of construction. Variables considered included the width of road and thickness of surface.

Results

Although per-mile maintenance and administration costs were estimated separately, Table 2 shows only the relation of the *sum* of per-mile maintenance and administration costs to mileage. Maintenance costs were generally about four times as large as administration costs, regardless of mileage administered. As a state average, maintenance costs made up 82 percent of total maintenance and administration costs in units administering 20 miles, and 85 percent in units of 70 miles.

The pattern of decreasing per-mile costs with increased mileages administered by the unit is evident in each state highway district. However, the per-mile costs decrease at a decreasing rate; that is, the cost reductions are greatest in the increases from the lower mileages.

Table 3 shows the costs per mile for the most common type of construction — gravel applied on graded and shaped gravel or crushed stone. In all, 581 projects were used in the analysis. The costs presented assume construction of different mileages at the average width and thickness shown for the particular state highway district considered or for the state.

Costs for certain less common types of construction — gravel on gravel, earth, or stone; low-type bituminous; and oil — are presented in Table 4. Altogether, 425 projects were considered in these analyses.

The pattern of decreasing per-mile costs with greater mileage is evident for each type of construction and each district.

Part II — A Detailed Study of Eleven Selected Road Units

Basic information

The eleven road units in this part of the study maintained an average of 43.28 miles, with the mileage varying from 18.57 to 79.83 (*see* Table 7, page 13). Actual expenditures by these units were taken from the annual reports of township supervisors (Table 5), and other cost data were computed from these. In addition, miscellaneous data and observations were obtained from personal interviews with highway commissioners, township supervisors, and clerks. The quality of roads in each township was determined by visual inspection.

The property tax is the major source of revenue for road units. The amount of money available for roads therefore depends on the assessed

Table 5. — Expenditures by Eleven Local Road Units, 1954

Road unit	Maintenance	Administration	Maintenance and administration	Construction	Total
Northern					
A	$ 2,730.88	$2,925.89	$ 5,656.77	$4,079.75	$ 9,736.52
B	4,118.16	3,042.16	7,160.32	.....	7,160.32
C	7,477.00	3,968.48	11,445.48	7,435.24	18,880.72
D	12,114.76	2,971.75	15,086.51	.....	15,086.51
Central					
E	4,722.34	1,289.92	6,012.26	.....	6,012.26
F	9,333.17	2,248.80	11,581.97	148.87	11,730.84
G	13,455.74	3,951.33	17,407.07	.....	17,407.07
Southern					
H	1,607.53	604.00	2,211.53	.....	2,211.53
I	5,049.88	1,670.22	6,720.10	3,895.31	10,615.41
J	2,005.37	1,668.12	3,673.49	.....	3,673.49
K	4,418.76	2,477.10	6,895.86	4,418.67	11,314.53

valuation and the tax rate. Valuation, tax rate, and total road levy for the eleven units are shown in Table 6.

Local road units can levy five different taxes for road purposes. Three of these taxes were levied by some or all of the eleven units studied (Table 6). Most important is the road and bridge tax, which can be as high as 0.165 percent without a referendum (0.175 percent in

Table 6. — Tax Rates, Total Levy, and Assessed Valuation of Eleven Local Road Units, 1953

Road unit	Tax rates				Assessed valuation	Total levy
	Road and bridge	Special bridge	Permanent road	Total		
Northern					*Thousand dollars*	*Dollars*
A	.100	....	....	.100	11,389	16,700
B	.102	.050	....	.152	4,632	10,300
C	.100	.050	.167	.317	7,039	22,955
D	.230	....	....	.230	7,558	16,700
Central						
E	.240	....	....	.240	2,662	6,400
F	.124	....	....	.124	6,174	7,600
G	.128	....	....	.128	13,562	22,800
Southern						
H	.103	....	....	.103	957	1,600
I	.095	....	....	.095	8,619	12,200
J	.105	....	....	.105	1,834	3,500
K	.107	....	.107	.214	4,503	38,021

Table 7. — Classification of Roads by Surface Type, Eleven Local Road Units

Road unit	Earth surfaces[a]		Gravel or stone		Bituminous[b]		Total miles
	Percent	Miles	Percent	Miles	Percent	Miles	
Northern							
A	0	0	18	3.27	82	15.30	18.57
B	8	1.68	51	11.08	41	8.98	21.74
C	3	1.50	97	46.87	0	0	48.37
D	2	1.25	98	55.24	0	0	56.49
Central							
E	17	3.81	83	18.20	0	0	22.01
F	0	0	91	42.45	9	4.28	46.73
G	5	4.36	91	71.92	4	3.55	79.83
Southern							
H	46	10.66	54	12.33	0	0	22.99
I	12	4.29	88	30.74	0	0	35.03
J	23	12.71	77	41.97	0	0	54.68
K	32	22.10	68	47.51	0	0	69.61

[a] Includes unimproved earth, graded and drained earth, and soil-surfaced earth.
[b] Includes only low-type bituminous (asphalt on a flexible base).

township districts). A special bridge tax — up to 0.05 percent — can also be levied. A third kind of levy is the permanent road or "hard road" tax, which can be as high as 0.167. Other possible sources of revenue are the road damage tax and the bond levy. The first of these can be collected for purchase of right-of-way, and the rate can be as high as 0.033. The bond levy is used as a basis for borrowing. There is no statutory limit on the rate, but it must be approved by the taxpayers in a referendum. None of the eleven units levied the road damage tax in 1953; nor did they have any income from the sale of bonds.

The type of road surface affects current expenditures for maintenance, and also reflects past expenditures. Table 7 shows the classification of roads in the various road units.

Another factor affecting costs is the quality of construction and maintenance. This can be approximated by determining road conditions and the adequacy of available equipment. The kind of equipment and its condition are shown in Table 8. Total equipment and building investment are shown in Table 9, together with the road conditions in each unit, as ascertained by visual inspection.

Also shown in Table 9 is population density. The number of people living in an area affects the use given the road system. Heavily traveled roads require more maintenance than lightly used roads and are usually of better quality.

Table 8. — Items of Equipment[a] Owned by Eleven Local Road Units, 1953

Road unit	Motor patrol	Pickup	Dump truck	Tractor	Mower	Loader	Snow plow		Sprayer	Tar kettle	Fuel tank	Road drags	Roller	Main-tainer	Mixer	Chain saw	Condition of equip-ment	Building
							Grader	Truck										
Northern																		
A.....	1	1	1	1	1	1	1	1									Good to excellent	Good—steel pole
B.....	1	1					1	1	1	1	1						Fair to good	Good—steel pole
C.....	1		1		1				1			17[b]	1	1			Poor to good	Fair—block
D.....	1		2			1	1	1	1								Good to excellent	Good—frame
Central																		
E.....	1	1		1													Fair to excellent	Good—metal frame
F.....	1		1				1	1			1						Fair	Good—metal frame siding
G.....	1		1	1			1	1	1					1	1	1	Good to excellent	Good—frame
Southern																		
H.....	1			1[c]										1[e]			Good	None
I.....	1																Good	None
J.....	1	1[d]		1[c]										1[e]			Excellent	None
K.....	1		1[e]	1[c]										1[e]			Good	None

[a] Small tools not listed.
[b] Loaned to farmers to drag roads with tractors.
[c] No longer in use.
[d] Rented by commissioner to road unit for $1.00 a day.
[e] Owned by road commissioner.

Table 9. — Condition of Roads, Investment in Building and Equipment, and Population Density, Eleven Local Road Units

Road unit	Miles	Road condition	Investment		Population		
			Equipment	Building	Total	Rural farm	Rural farm per mile
Northern							
A.....	18.57	Fair	$15,700	$ 900	3,404	377	20
B.....	21.74	Good	6,800	2,200	1,077	356	16
C.....	48.37	Good	21,094	1,000	1,440	666	14
D.....	56.49	Good	18,000	1,200	1,378	628	11
Central							
E.....	22.01	Good	13,500	1,500	206	206	9
F.....	46.73	Excellent	17,275	1,200	689	689	15
G.....	79.83	Excellent	31,935	600	2,355	829	10
Southern							
H.....	22.99	Poor	3,700	0	741	333	14
I.....	35.03	Good	4,800	0	4,965	970	28
J.....	54.68	Fair	9,000	0	688	688	13
K.....	69.61	Fair	10,000	0	2,018	907	13

Analysis

Variations in total expenditures. What causes variation in total expenditure for road purposes? Of the various factors (mileage maintained, available funds, road classification, quality of roads, and population density), there is evidence that amount of available funds is most important.

As shown in Tables 5 and 6, total expenditure varies approximately with the levy. Differences between levy and expenditures can be partially explained by the fact that 50 percent of the road and bridge levy paid by municipalities must be turned back to them. The presence of villages in a unit is roughly indicated by the difference between total and rural farm population (Table 9).

As might be expected, levy and consequently total expenditures change in the same direction as the assessed valuation. In the rest of this analysis, therefore, valuation has been used as representative of available funds.

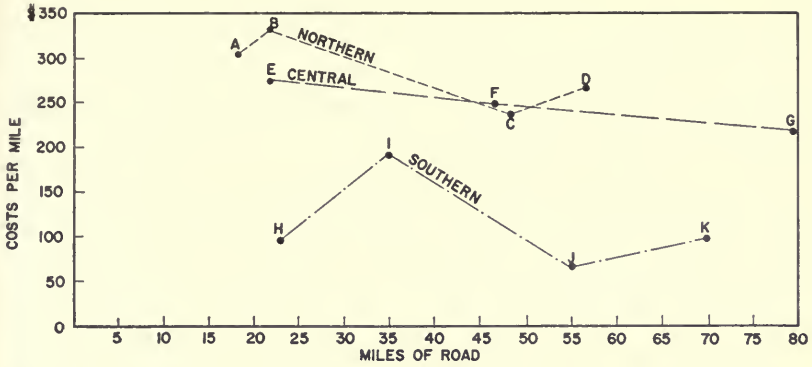
Total expenditure generally increases with mileage, although there is no consistent relationship.

Variations in per-mile expenditures. Table 10 shows mileage maintained, condition of roads, per-mile expenditures and investment in building and equipment, population density, and valuation per mile.

As shown in Table 10, and also in Fig. 2, total maintenance and administrative expenditures per mile show a general downward trend

Table 10. — Type and Condition of Road, and Per-Mile Expenditures, Equipment and Building Investment, Farm Population, and Valuation, Eleven Local Road Units

Road unit	Miles of road				Condition of road	Expenditures per mile					Equipment and building investment per mile	Rural farm population per mile	Assessed valuation per mile
	Earth	Gravel	Bituminous	Total		Maintenance	Administration	Maint. plus admin.	Construction	Total			
Northern													
A.....	0	3.27	15.30	18.57	Fair	$147	$158	$305	$219	$524	$893	20	$613
B.....	1.68	11.08	8.98	21.74	Good	189	140	329	0	329	414	16	213
C.....	1.50	46.87	0	48.37	Good	155	82	237	153	390	457	14	146
D.....	1.25	55.24	0	56.49	Good	214	53	267	0	267	340	11	134
Central													
E.....	3.81	18.20	0	22.01	Good	215	59	274	0	274	681	9	121
F.....	0	42.45	4.28	46.73	Excellent	200	48	248	3	251	396	15	132
G.....	4.36	71.92	3.55	79.83	Excellent	169	50	219	0	219	408	10	170
Southern													
H.....	10.66	12.33	0	22.99	Poor	70	26	96	0	96	161	14	42
I.....	4.29	30.74	0	35.03	Good	144	48	192	111	303	137	28	246
J.....	12.71	41.97	0	54.68	Fair	37	31	68	0	68	165	13	34
K.....	22.10	47.51	0	69.61	Fair	63	36	99	64	163	144	13	65



Per-mile maintenance and administrative costs of eleven road units as compared with miles per unit. (Fig. 2)

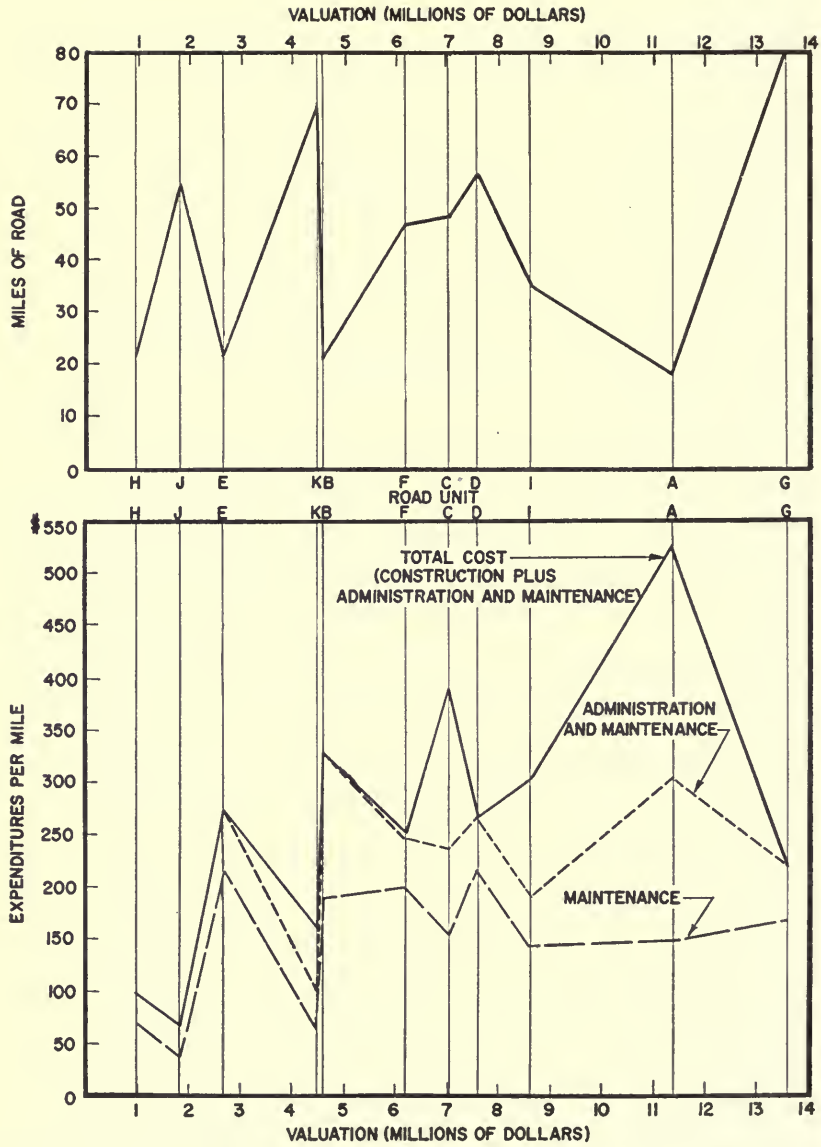
as miles increase in the central and northern areas. Although a similar trend is apparent in the southern area, there is more variation among units than in the other two regions. In both the southern and the central areas, maintenance costs vary much more than administrative costs.

Part of the variation in expenditures between townships may be attributed to the type and condition of the roads. This is especially true in the southern area, which showed a great deal of inconsistency in expenditures and also in the quality of the roads. Unit I, which had by far the highest cost per mile, had the best-maintained roads and the highest percent of gravel road in that area, as well as the greatest population density.

Unit I also had the highest assessed valuation in the southern area. Valuation appears to be at least as important as miles in explaining variations in per-mile costs in this area. This is brought out in the lower part of Fig. 3, which indicates that total expenditure per mile does tend to increase as the tax base increases. However, the upper part of the chart shows that miles of road maintained tend to vary inversely with the expenditures per mile. As already mentioned, a similar trend is brought out in Fig. 2, which compares maintenance and administrative costs per mile to miles of road.

Investment in equipment and buildings varies greatly among units (Table 10). As would be expected, this is reflected in a great variation in kind and condition of equipment, the only exception being motor patrols. Some equipment belonged to the highway commissioner, who leased it to the road unit.

Motor patrols were used an average of 95 days a year, and the average value was $5,172. In the southern area, they were about



Costs per mile in eleven road units tended to vary directly with assessed valuation and inversely with miles of road. (Fig. 3)

the only machinery in service, and no housing was used to protect them from the elements.

No attempt is made in this study to relate investment or condition of equipment to cost per mile. Nor is any attempt made to evaluate the work time per year of commissioners, which varied from 92 to 284 days a year.

Differences among areas. As shown in Table 10, expenditures per mile tend to be highest in the northern area and lowest in the south. This is primarily due to a difference in valuation and hence in income. Northern areas, however, do have higher costs for snow removal and more frost damage to roads.

The southern area, in general, ranks lower than the northern and central areas in expenditures per mile, valuation, investment, and type and condition of road. Also, the southern road units have less equipment and no housing for it. Not only does southern Illinois have less money to spend on roads than the rest of the state, but it has more problems in building and maintaining roads. More bridges and culverts are needed in the hilly sections, and road materials often have to be hauled farther than in the northern and central areas.

The central area has fewer special problems than either of the other areas. It has to face the problem of snow removal, but not to the same extent as the northern area. Damage by frost action is also less than in the northern area. In general, the central area falls between the other two areas in valuation and expenditures per mile.

Application of Results

There appears to be ample justification for the belief that costs per mile decrease as the miles maintained by the administering unit increase. This, of course, is not surprising. The magnitude of the per-mile cost decrease, however, needs to be weighed carefully in considering the desirability of enlarged administrative units. The evidence presented in Part I of this bulletin indicates that considerable saving might be expected from merging the smallest units into larger ones, but that the savings from enlarging units beyond 50 or 60 miles would not be substantial.

A comparison of the costs (using state average figures from Tables 2 and 3) of one 60-mile unit, two 30-mile units, and three 20-mile units will suggest the amount of savings possible by consolidating small

units into larger ones. Assuming that 5 percent of the total mileage is new construction of gravel applied to a previous gravel surface, we have the following costs:

	One 60-mile unit	*Two 30-mile units*	*Three 20-mile units*
Maintenance and administration costs (60 miles)	$14,160	$16,140	$18,180
Construction costs (3 miles)	8,511	9,663	10,818
Total	$22,671	$25,803	$28,998

The saving to be expected from consolidating two 30-mile units into one 60-mile unit is about 12 percent; from consolidating three 20-mile units, about 22 percent.

It is not believed that enough experience has been obtained to evaluate the amount of per-mile cost reduction that would be expected from consolidation into a county system. All of the five county-wide administrative units are in the extreme southern area (Highway District 9), and only one of these has over 400 miles. In many counties consolidation would mean a system of substantially more than 400 miles.

A detailed analysis of eleven road units (Part II of the study) showed results for central and northern Illinois that confirmed the findings of Part I. For example, a comparison of units B and D, each having roads in "good" condition, shows that the small unit (21.74 miles) spent 23 percent more per mile than the large unit (56.49 miles). The results of the case study in southern Illinois are not conclusive because the small sample that was used varied widely in assessed valuation and in condition of the roads.

Appendix — Statistical Methodology

Cost functions were fitted by the multiple regression technic.[1] A maintenance cost function and an administration cost function for each state highway district were estimated. To illustrate the procedure of deriving per-mile costs from such functions for presentation in text tables, we present as an example the following cost equations based on 177 local road administrative units in State Highway District 7.

$$(1)\ Y_m = -328 + \underset{(119.07)}{191.85}\,X_1 + \underset{(28.52)}{29.43}\,X_2 + \underset{(34.41)}{93.18}\,X_3 + \underset{(16.74)}{71.39}\,X_4 + \underset{(470.53)}{278.16}\,X_5 - \underset{(11,063)}{6,930}\,X_6 - \underset{(1,358)}{1,010}\,X_7 - \underset{(12,994)}{3,865}\,X_8 + \underset{(0.051)}{0.481}\,X_9$$

$$(2)\ Y_a = 273 + \underset{(24.224)}{67.845}\,X_1 + \underset{(5.819)}{0.869}\,X_2 + \underset{(7.019)}{24.292}\,X_3 + \underset{(3.413)}{22.081}\,X_4 + \underset{(95.9)}{42.5}\,X_5 + \underset{(2,246.9)}{2,942.4}\,X_6 + \underset{(276.8)}{319.6}\,X_7 + \underset{(2,637.1)}{465.1}\,X_8 + \underset{(0.010)}{0.046}\,X_9$$

Symbols have the following meanings:

Y_m = maintenance cost (dollars)
Y_a = administration cost (dollars)
X_1 = unimproved roads (miles)
X_2 = graded and drained earth roads (miles)
X_3 = soil surfaced, primarily oil roads (miles)
X_4 = gravel or stone roads (miles)
X_5 = bituminous (low type) roads (miles)
X_6 = bituminous (high type) roads (miles)
X_7 = concrete roads (miles)
X_8 = brick roads (miles)
X_9 = assessed valuation (thousands of dollars)

The number in parentheses immediately below each regression coefficient is the standard error of that regression coefficient.

To find the average variable maintenance or administration cost per composite mile, each of the regression coefficients corresponding to a road mileage variable (X_1 through X_8) is multiplied by the average percentage of that particular type of road in Highway District 7 (see Table 1). For the maintenance cost equation we have (191.85) (4.889%) + (29.43) (25.017%) + . . . −(3,865) (0.003%) = $68.26 as the average variable maintenance cost per composite mile. To determine the total fixed maintenance cost per composite mile, the assessed valuation X_9 is assumed to be at its mean value ($4,030,000). Multiplying this value by the regression coefficient for X_9 and adding the constant (−328), we get $1,610 as the fixed maintenance cost.

[1] See any standard statistical reference, *e.g.*, Ezekiel, Mordecai, *Methods of Correlation Analysis*, John Wiley and Sons, New York. 1941.

An identical procedure is followed with the second equation to obtain average variable administration costs and total fixed administration costs. For Highway District 7 these values are \$19.50 and \$458 respectively. Adding the fixed maintenance and administration costs we get \$1,610 + \$458 = \$2,068. Adding the variable maintenance and administration costs per composite mile we get \$68.26 + \$19.50 = \$87.76. The total cost per composite mile may then be computed for any mileage within the range of the observations. For example, the cost per mile of a 20-mile unit would be \$2,068 divided by 20 plus \$87.76 or \$191.16 (see Table 2).

Construction costs were also estimated by the multiple regression procedure. Taking as an example the 106 projects in Highway District 7 involving the application of gravel to a surface of graded and shaped gravel or crushed stone, we have the following equation:

$$(3)\quad Y_c = \underset{}{-4{,}086} + \underset{(158)}{2{,}413}\,X_1 + \underset{(72)}{116}\,X_2 + \underset{(176)}{1{,}160}\,X_3$$

In this equation symbols have the following meanings:

Y_c = construction cost (dollars)
X_1 = length of project (miles)
X_2 = width of surface applied (feet)
X_3 = depth of surface applied (inches)

At the average width (13.17 feet) and average depth of surface (3.10 inches) for this group of projects, the total fixed costs are (116) (13.17) + (1,160) (3.10) −4,068 = \$1,038. Using the coefficient of X_1, \$2,413, as the variable cost per mile of road constructed, the total cost per mile for mileages within the range of data may be estimated by dividing total fixed cost by the mileage and adding \$2,413 (see Table 3).

The cost equations had the following multiple correlation coefficients; all are statistically significant at the 1-percent level of probability:

	Multiple correlation coefficient		
Highway district	*Maintenance*	*Administration*	*Construction*
1	.93	.74	.80
2	.90	.71	.71
3	.79	.60	.70
4	.61	.66	.81
5	.84	.66	.98
6	.91	.73	.79
7	.76	.66	.84
8	.81	.74	.93
9	.92	.78	.79

The square of the multiple correlation coefficient gives the percent of total variation in cost among units that is accounted for by the variables included in the analysis. For example, 87 percent ($.93^2$) of the variation in maintenance costs among units in District 1 is due to mileage and assessed valuation. In general, these two variables are more important in accounting for variation of maintenance costs among units than variation of administration costs. In District 3, only 36 percent of the total variation of administration costs is explained by mileage and assessed valuation.